

Setting up an Integrated Rabies Control Model in Cote D'ivoire

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Abstract

Since 2008, Cote d'Ivoire has classified rabies as a notifiable disease and one of the five priority zoonoses in 2017. An integrated national rabies control plan was drawn up following assessment of the disease burden and prioritization of rabies. The situational analysis carried out highlighted the discrepancy between the characteristics of rabies in Cote d'Ivoire and the activities implemented, which explains the persistence of the disease. In this context, we posed the research question of what model, adapted to the characteristics of rabies, could be recommended, based on the determinants of mortality, to accelerate progress towards its elimination in Cote d'Ivoire. The aim of this study was to propose an integrated rabies control model adapted to the characteristics of the disease.

We conducted a qualitative cross-sectional study from January 2023 to June 2023 based on a literature review. It covered all the work carried out on rabies between 1995 and 2023. The studies carried out were first grouped under 3 headings using the SWOT method. Next, a problem tree was constructed to highlight the mortality factors due to human rabies. Finally, based on the problems, integrated interventions in the form of an integrated model were constructed to accelerate progress towards the elimination of rabies in Cote d'Ivoire.

The Main Challenges Highlighted in the Fight against Rabies in Cote d'Ivoire Were:

A problem tree developed to highlight the factors associated with mortality, based essentially on the low vaccination coverage of dogs, the lack of knowledge that leads to low uptake and non-compliance with the PPE.

A Model to accelerate progress towards the elimination of rabies in Cote d'Ivoire incorporating interventions that, if implemented, could improve uptake and compliance with PEP in addition to increasing vaccination coverage in dogs. This model includes a combination of several methods, the main pillars of which are improving geographical and financial accessibility, increasing knowledge and encouraging people to take ownership of the fight against rabies.

Conclusion: Pending control of the reservoir and vector of the disease, the integrated model of rabies control should be systematically implemented, based on PEP before any exposure to rabies, raising public awareness and improving access to PEP.

Keywords: Rabies Control; Viral Disease; Zoonosis Affects; Epidemiological

Introduction

Rabies is a viral disease that almost always progresses to death as soon as the first signs appear [1]. It is ranked 10th among fatal infectious diseases and remains one of the most serious diseases transmissible to humans [1]. Dogs are the main animal reservoir species in the world, accounting for around 99% of human deaths. According to the WHO, this zoonosis affects more than 150 countries worldwide, with more than 59,000 deaths estimated annually [1] and more than 3.7 million disability-adjusted life years (DALYs) estimated to be lost each year [2]. It could be responsible for more than one million deaths in the 67 endemic countries between 2020 and 2035 if nothing is done [3]. Rabies is most prevalent in Asia and Africa, where more than 95% of cases are recorded [1]. The animal responsible for transmitting the disease to humans in these two continents is still the dog in almost 99% of cases, and more than 40% of the victims of this zoonosis are under 15 years of age [1].

In Cote d'Ivoire, rabies is endemic and deaths linked to the disease are regularly reported by the national epidemiological surveillance system [4]. Since 2008, the country has classified rabies as a notifiable disease and one of the five priority zoonoses in 2017 [5, 6]. In 2015, an initiative to eliminate dog-transmitted rabies by 2030 was taken [1].

An integrated national rabies control plan was put in place following Cote d'Ivoire's accession to this initiative.

Indeed, the global rabies elimination initiative was the determining factor in the development and implementation of the integrated national rabies control plan. Indeed, in the local context of Cote d'Ivoire and most other African countries, rabies was a neglected tropical disease characterized by a scarcity of resources for control.

The implementation of this plan has led to an intensification of joint activities: communication, dog vaccination, capacity building for agents in both sectors, investigation and response organized according to the "one Health" concept, in addition to Post-Exposure Prophylaxis.

Even though rabies is a notifiable disease in both humans and animals, and that there is an integrated national Programme to combat this zoonosis, the number of deaths from rabies transmitted by dogs continues to persist and is tending to increase. This situation takes us further away from the major indicator - "No human deaths due to rabies for 24 months" - required for a country to be internationally recognized as having eliminated rabies as a public health problem [1]. Evaluation of the activities carried out revealed that they were not adapted to the characteristics of the disease in Cote d'Ivoire. In this context, we asked ourselves the following question: what model adapted to the characteristics of rabies could be recommended, based on the determinants of mortality, to accelerate progress towards the elimination of rabies in Cote d'Ivoire? We put forward the following hypothesis: an integrated model adapted to the characteristics of rabies based on the determinants of this zoonosis could enable it to be eliminated by 2030 in Cote d'Ivoire.

The Objectives Were

- Carry out a situational analysis of rabies control activities in Cote d'Ivoire based on a literature review
- Develop a problem tree for human rabies deaths and an integrated model for rabies control in Cote d'Ivoire
- Propose an integrated control model to improve rabies control in Cote d'Ivoire.

Material and Method

Type and Period of Study

We conducted a qualitative cross-sectional study from January to July 2023. This was a systematic review of all our work on rabies. A systematic review is the most exhaustive identification and review of the literature on a specific topic, in a specific field, covering a specific period [8].

Article Eligibility Criteria

The review included studies on rabies of which we were co-author in the period from 1995 to 2023. All types of published studies were included. Scientific papers on rabies presented at congresses and published, and publications of interviews in the press or Wikipedia were not included in the study.

Search Strategies and Sources of Information

- We searched the following databases:
- Pubmed / Medline
- Electronic university databases
- Journal websites
- Internet search engines (Google Scholar)
- Author reprints received from journals.

Data Management

- The main information extracted from the selected studies included for each study:
- Journal of publication
- The authors
- The title of the study
- Year of publication
- Number of pages

- Access link to the article.

The information extracted, including the following variables, was grouped into 4 themes:

- The characteristics of rabies in Cote d'Ivoire (risk factors for death)
- The list of activities implemented as part of the fight against rabies in Cote d'Ivoire
- The limitations of the interventions implemented
- A situational analysis of the institutional framework for rabies control, highlighting strengths, weaknesses, opportunities, and threats

Data Analysis

All the studies were grouped together and analyzed, with summaries presented in the form of text, figures, and tables to summarize and present the results of the studies included. The situational analysis was first carried out by considering human and animal activities in accordance with the "one health" concept and using the SWOT tool (Strengths, Weaknesses, Opportunities and Threats), which enabled us to define the strengths, weaknesses, opportunities, and threats of rabies control in Cote d'Ivoire. Then, using the data from the articles, we constructed a problem tree of human rabies deaths in Cote d'Ivoire. Finally, this problem tree served as a basis for the construction of the integrated model for rabies management in Cote d'Ivoire.

Ethical Considerations

As this study is a systematic review, it does not directly involve human or animal subjects. It therefore does not require ethical approval by the French National Committee for Ethics in Health and Life Sciences (CNESVS).

Results

Situational Analysis of Rabies Control Activities in Cote d'Ivoire

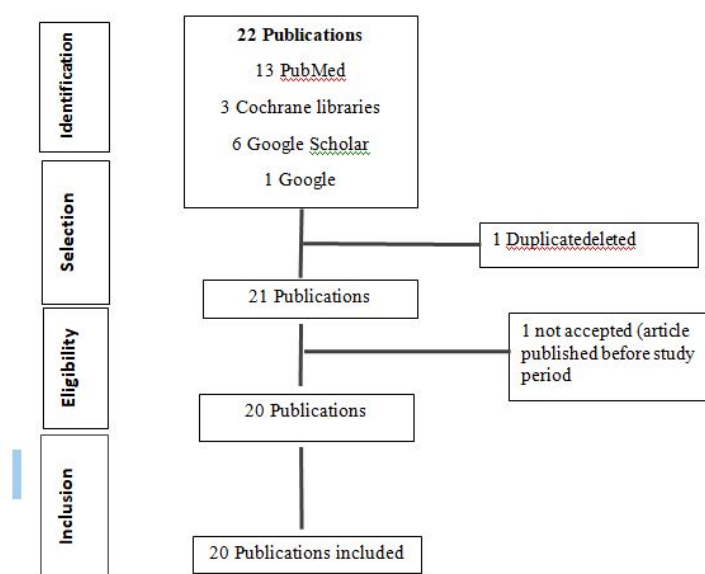


Figure 1: Article management flow chart

The literature review identified a number of publications from which we removed duplicates and selected 23. Of these publications, one was excluded on the basis of duplicates and 1 article published before the study period was not retained, so 20 were selected for inclusion in full text.

The following table shows the characteristics of the articles selected for systematic review.

In order to gain a better understanding of the implementation of an integrated rabies control model in Cote d'Ivoire, a comparative analysis of the literature on the subject was carried out. The synoptic table below (Table 1) lists the authors who have addressed the question of rabies epidemiology. This list is not exhaustive, and the designations adopted do not systematically correspond to the first use of the concepts by their originators.

The results of the SWOT analysis of rabies control interventions carried out on the basis of the articles selected are shown in Table II.

Table 1: Characteristics of articles included in the systematic review

Revues	Auteurs	Titres	Annees	Liens
Medecineetmaladiesinfectieuses	Tiembre a, S. Dagnan a, A. Douba a, E.V. Adjogoua b, HB ourhy c, L. Dach eux c, L. Kouassi d, M. Dosso b, P . Odehouri-Koudou a	Epidemiological surveillance of human rabies in the context of a canine rabies endemic in Côte d'Ivoire	2010	https://doi.org/10.1016/j.medmal.2010.01.008
Public health	IssakaTiembre, Joseph Benie Bi Vroh, Damus Paquin Kouassi, Harvey Attoh-Toure, Kouadio Daniel Ekra, Aly Diane, N'cho Simplicie Dagnan, Janine Tagliante-Saracino	Knowledge, attitudes and practices of heads of household in the commune of Abobo (Abidjan, Côte d'Ivoire) with regard to rabies, in 2008.	2014	https://doi.org/10.3917/spub.144.0547
PLoS Negl Trop Dis	Issaka Tiembre, Anaïs Broban, Joseph Benie, Mathilde Tetchi, Sophie Druelles, Maïna L'Azou	Human rabies in Côte d'Ivoire 2014-2016: Results following reinforcements to rabies surveillance.	2018	https://doi.org/10.1371/journal.pntd.0006649 .
Journal of epidemiology and public health	B.Y.G. Zamina, I. Tiembre, K. N'Guessan, T.A.S.R. N'Krumah, H. Attoh-Toure, S.M. Tetchi, J. Benie.	Influence of the knowledge of patients consulting the Treichville rabies centre, Cote d'Ivoire, on compliance with post-exposure prophylaxis.	2019	https://doi.org/10.1016/j.respe.2019.01.118
PLoS Negl Trop Dis	Anaïs Broban, Mathurin C, Tejiokem, Issaka Tiembre, Sophie Druelles, Maïna L'Azou*	Bolstering human rabies surveillance in Africa is crucial to eliminating canine-mediated rabies	2018	https://doi.org/10.1371/journal.pntd.0006367

Public health	Issaka Tiembre (1), Joseph Vroh Benie Bi (1), Simplice N'Cho Dagnan (1), Daniel Kouadio Ekra (1), Sonia Zebe (2), Janine Tagliante-Saracino (3)	Epidemiological profile of people exposed to rabies in Abidjan, Côte d'Ivoire	2011	DOI10.3917/spub.114.0279
Acta Tropica	Mathilde Sopi Tetchi, M'Begnan Coulibaly, Vessaly Kallo, Gnamien Sylvain Traore, Tiembre Issakaa, Beniee Bi Vroh Joseph, Felix Gerber, Jasmina Saric, Monique Lechenne, Jakob Zinsstag, Bassirou Bonfoh Jakob Zinsstag, Bassirou Bonfoh	Risk factors for rabies in Cote d'Ivoire	2020	https://doi.org/10.1016/j.actatropica.2020.105711
Public health	Issaka Tiembre, Diloma Marie Brigitte Aka-Kone, Yao Eugene Konan, Joseph Benie Bi Vroh, Kouadio Daniel Ekra, N'cho Simplice Dagnan, Joseph Aka, Janine Tagliante-Saracino, Paul Odehouri-Koudou.	Compliance with rabies vaccination in people exposed to rabies in Abidjan (Côte d'Ivoire).	2009	https://doi.org/10.3917/spub.096.0595
Tropical medicine	Tiembre I, Benie J, Ekra D, Douba A, Kouame B, Dagnan S, Tagliante-Saracino J.	Compliance with veterinary surveillance at the Abidjan rabies centre	2008	Med Trop2008; 68 : 514-518
Tropical Medicine and Health	B.Y.G. Zamina , I. Tiembre , H. Attoh-Toure, K.E. N'Guessan, S.M. Tetchi , B.V.J. Benie.	Factors associated with the abandonment of post-exposure prophylaxis at the Abidjan rabies centre, Côte d'Ivoire.	2018	10.1684/mst.2018.0796
Vaccine	N. Sreenivasan 1, A. Li 2 , M. Shiferaw 1 , C.H. Tran 1 , R. Wallace 1 , J. Blanton 1 , L. Knopf 3 , B. Abela-Ridder 3 , T. Hyde 1 , U.R. Siddiqi, S. Tahmina a , K. Penjor b , L. Sovann c , Y. Doeurn c , K. Sim c , V. Houssiere d , M. Tejiokem e , R. Mindekem, L. Yu, Y. Wenwu g , J. Benie h , M. Tetchi h , I. Tiembre h , e t a l	Overview of rabies postexposure prophylaxis access, procurement and distribution in selected countries in Asia and Africa, 2017–2018	2019	https://doi.org/10.1016/j.vaccine.2019.04.024

Bulletin de la societe de pathologie exotique	I. Tiembre · J. Benie · H. Attouh-Toure · P. Zengbe-Acray · S.M. Tetchi · D. Kpebo · A.P. Lezou · S. Dagnan	Abandon de la prphylaxie post exposition au Centre antirabique d'Abidjan, Côte d'Ivoire	2013	DOI 10.1007/s13149-013-0312-y
Malian Journal of Infectiology and Microbiology	Coulibaly M'begnan ¹ , Kouassi Damus Paquin ¹ , ² Yao Gniassan Henri auguste ^{1,2} , KouameArsene Deby ¹ , Konan N'Guessan ¹ , Soumahoro Sory Ibrahim ^{1,2} ; Attouh-Toure Harvey. ³ , Tiembre Issaka	Determinants of the abandonment of post-exposure rabies prophylaxis at the Bouake Rabies Centre; Cote d'Ivoire	2017	https://doi.org/10.53597/remim.v0i10.956
OJEPi	Issaka Tiembre , Tetchi Sopi Malthide , Akani Bangama , Christiane Djoman , Joseph Benie Bi	Analysis of epidemiological investigations and responses to human rabies deaths in Cote d'Ivoire, 2021	2023	https://doi.org/10.4236/ojepi.2023.133016
ActaTropica	MathildeTetchi, M'BegnanCoulibaly, VessalyKallo, GnamienSylvainTraore, TiembreIssaka, Benie Joseph, Felix Gerber f, Monique Lechenne, JakobZinsstag, BassirouBonfoh.	The Thai Red Cross protocol experience in Cote d'Ivoire.	2020	https://doi.org/10.1016/j.actatropica.2020.105710
Public health	Bi Yourou Guillaume Zamina, Issaka Tiembre, Konan N'Guessan, Harvey Attouh-Toure, Sopi Mathilde Tetchi, Bi Vroh Joseph Benie.	Improving compliance with post-exposure prophylaxis through the use of mobile phones, Cote d'Ivoire	2018	DOI10.3917/spub.185.0545
Advances in Infectious Diseases	Bi Yourou Guillaume Zamina ¹ , Assikohon Pulcherie Gouzile ¹ , Martial Bama ¹ , Ellele Aime Yapi ¹ , Youssouf Diabate ¹ , Tetchi Sopi Malthide ¹ , Tiembre Issiaka	Involvement of Healthcare Staff from First Contact Health Establishments in the Elimination of Human Rabies in the Health Districts of Ferkessedougou and Kong in Ivory Coast, 2020	2020	https://doi.org/10.4236/aid.2022.124059

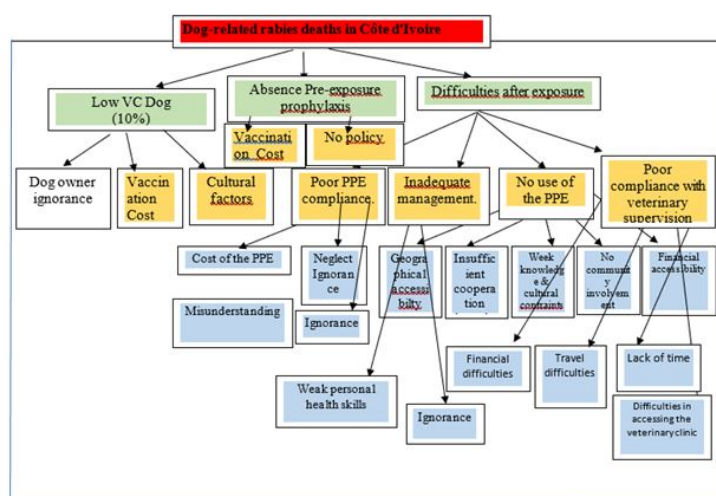
Vaccine	Issaka Tiembre, Christiane Djoman, Tetchi Sopi Malthide, Acho Albertine, Joseph Benie Bi .	Feasibility and benefits of a Preexposure vaccination campaign against human rabies in students under 15 y ears of age: Experience of four (4) health districts in Cote d'Ivoire.	2023	DOI: 10.35248/2157-7560.23.14.521
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Table 2: Results of the SWOT analysis of rabies control interventions in Cote d'Ivoire

Strengths	Weaknesses
<ul style="list-style-type: none"> - Rabies communication activities (JMR, response activities, School, GARC training, local rabies committees) - Surveillance of human and animal rabies through the animal and human rabies surveillance system Joint investigation and response in the event of detection of human rabies- Vaccination of exposed persons as part of the PPE offer - Routine dog vaccination, punctuated by vaccination campaigns- Feasibility studies to guide decision-making (pre-exposure vaccination, intradermal protocol, involvement of CHWs)- Multi-sectoral collaboration in implementing activities (organization of JMR, investigations and response)development of protocols for the management of people exposed to rabies - Establishment of a network of rabies centers throughout the country 	<ul style="list-style-type: none"> - Ad hoc communication activities- Insufficient collaboration and exchanges Little joint investigation/response- Implementation limited to INHP and UNIVAR branches- Low vaccination coverage of dogs- Convincing results of feasibility studies, but scale-up not yet effective- Low dog vaccination coverage - Financial inaccessibility of populations to PEP (high cost of PEP)- Geographical inaccessibility to PEP - No policy or guidelines for implementing preventive rabies vaccination in Cote d'Ivoire - Weak collaboration between the 2 sectors- Protocols for managing people exposed to rabies not updated- Low public awareness of rabies - Low community participation in communication activities (non-appropriation)
Opportunities	Threats
<ul style="list-style-type: none"> - Existence of political will- Involvement of partners- Existence of an integrated rabies control plan ; - Adherence of the country to the initiative to eliminate canine rabies by 2030. - Involvement of technical and financial partners in implementing national plan activities- Integration of Covid 19 vaccination activities 	<ul style="list-style-type: none"> - Impact of COVID19 on rabies activities- Vaccine supply difficulties- Low funding for plan activities

The problem tree of human rabies deaths transmitted by dogs and the integrated rabies control model in Cote d'Ivoire

The problem tree of dog-transmitted human rabies deaths

**Figure 2:** Problem tree of human rabies deaths transmitted by dogs in Cote d'Ivoire

According to Figure 2, the problem tree for dog rabies deaths in Cote d'Ivoire, there are three main causes of dog rabies deaths.

Low Vaccination Coverage of Dogs

The low vaccination coverage of dogs (10%) is mainly due to ignorance on the part of dog owners, the cost of the vaccine and cultural factors.

Lack of Pre-Exposure Prophylaxis

The cost of vaccination and the lack of policy and guidelines for implementing rabies vaccination are responsible for the lack of pre-show prophylaxis.

Difficulties after Exposure

Poor compliance with veterinary surveillance, failure to use PEP, inadequate care and the absence of a policy and guidelines for implementing rabies vaccination are the main difficulties encountered after exposure.

Integrated rabies Control Model in Cote Divoire

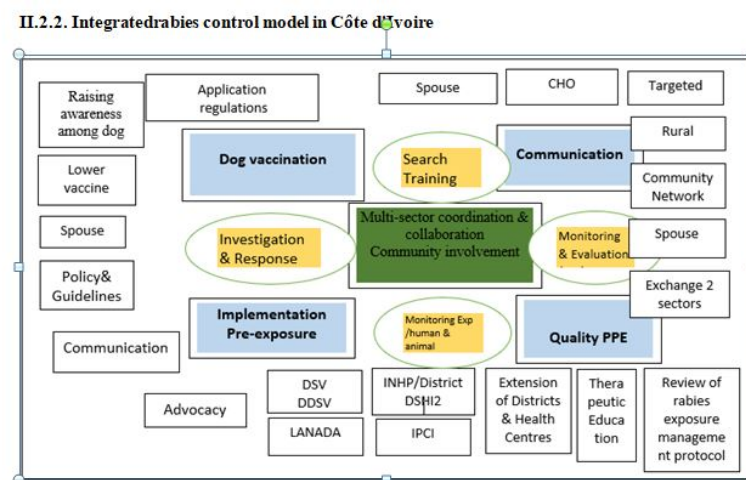


Figure 3: Integrated rabies control model in Cote d'Ivoire

In Figure 3, the integrated rabies control model is based on:

Adoption of the Reduced WHO Protocol

Use of the WHO's reduced protocol should be generalised immediately, as intradermal administration of rabies vaccine reduces costs and saves on doses.

Extending the offer of PEP to all District Public Health Centres

The extension of the PEP offer to all health districts in Cote d'Ivoire should be advocated. In the health districts, the availability of PEP should be ensured in the health centres. This extension of supply is necessary to bring PEP services closer to people at risk and to ensure that PEP is used and adhered to. In addition, improving geographical accessibility must go hand in hand with capacity-building and the effective involvement of health workers in first-contact health establishments in the care of people exposed to rabies.

Implementation of Prep Vaccination

This will make it possible to protect children, for whom certain exposures go undetected or where parents or guardians refuse to care for them.

Stepping up Animal Vaccination

Intensified vaccination of pets, and dogs, should achieve vaccination coverage of at least 70% over 5 years to control the canine reservoir.

Multi-Sectoral Coordination and CollaborationCommunity Participation

Discussion

Limitations of the Study

This study has several limitations, including the fact that it was based on a literature review, which was not exhaustive. In addition, a field survey could have strengthened this study in the development of the problem tree of human rabies deaths transmitted by dogs and the integrated rabies control model in Cote d'Ivoire. Despite these limitations, the study remains relevant and could help to improve rabies control in Cote d'Ivoire.

Situational Analysis

The primary cause of human rabies deaths in Cote d'Ivoire is people's low level of knowledge about how to behave towards their pets, particularly dogs, and above all the lack of recourse to PEP after exposure to rabies. This situation is exacerbated by the low vaccination coverage among dogs and viral circulation.

People's behaviour towards dogs' stems from their relationship with the dogs that are used, without reference to the associated responsibility. From this point of view, the animals are not vaccinated, and the cost of vaccines is also an obstacle, as is the failure to apply current regulations on the possession and movement of animals. Compliance with veterinary supervision is very low, which reinforces the notion that animal owners are not responsible. After exposure to rabies, the low use of PPE is explained by ignorance of rabies, but two other factors linked to the health system have been highlighted: geographical and financial inaccessibility.

The Decision Tree for Human Rabies Deaths

The Cost of Vaccination, a Consequence of the Low Vaccination Coverage of Dogs and the Absence of Prep and Ppe

One of the most important factors identified in human rabies deaths transmitted by dogs in Cote d'Ivoire is the cost of vaccination. The direct cost of PEP is still high in Cote d'Ivoire (between 32,000F and 40,000F CFA); this cost does not consider the indirect cost in terms of transport and time spent travelling to treatment centres. These financial factors act as a brake not only on uptake, but also on compliance with PEP. In Burkina Faso, a dose of VAR costs 7,500 CFA francs, yet 5 doses are needed for full immunisation, or 37,500 CFA francs for post-exposure treatment in the event of a suspected bite [9]. In Cambodia, the cost of full PPE against rabies has been estimated at between 50% and 100% of a Cambodian farmer's monthly salary [10]. A study in rural Tanzania showed that for a full course of PEP excluding GIR, a rural Tanzanian patient would have to pay more than USD 100 after a 5-dose regimen. In addition, there are inequalities such as travel costs for rural patients more than double those of patients in urban areas [11].

Geographical Accessibility

Geographical inaccessibility to PEP is also a major factor in non-use of PEP. In Burkina Faso, the anti-rabies vaccine is not available in all regions of the country, and there are only two anti-rabies treatment centres in the two major cities (Ouagadougou and BoboDioulasso) for the whole country [9]. In Cambodia, [12] showed a significant negative association between travel time to the Institute Pasteur du Cambodge (IPC) and Post-Exposure Prophylaxis compliance: a one-hour increase in travel time between patients' homes and IPC PEP centres leads to a 70% to 80% reduction in PEP compliance [12]. In Cote d'Ivoire, apart from the 30 INHP branches and the 30 health districts with Rabies Vaccination Units (UNIVAR), patients in other localities are obliged to travel long distances, losing hours or even days of their professional activities, which for some are their only source of income. Under these conditions, the use of and compliance with PEP is neglected. We therefore need to decentralise and increase the number of centres providing care for people exposed to rabies, and continue public awareness campaigns to change the behaviour of animal owners, especially dogs [9].

The Integrated Rabies Control Model in Cote Divoire

Several strategies have been implemented in the fight against rabies in Cote d'Ivoire.

The recommended model is essentially based on the ecohealth approach and is adapted to the characteristics of rabies in Cote d'Ivoire. By identifying community participation as the basis for all interventions, the ecohealth approach has enabled communities to become autonomous and to take control of the fight against rabies by themselves and for themselves. The ecohealth approach involves bringing together scientists, decision-makers, and community members to work together to improve human health by finding solutions through the way people interact with their environment. It recognises the interdependence of human health, animal health and ecosystem health [13]. It is highly participatory in nature, which means that citizens and their representatives are part of the entire research process, from the definition of the issue to the implementation of the collectively chosen solution. To achieve the goal of eliminating rabies by 2025, set by the Global Alliance for Rabies Control (GARC), we will need to go beyond veterinary and human medicine and include biology, cultural sciences, sociology, and geography. This ecohealth research approach was used by Audrey Simon to solve the problems associated with dogs in Kuujjuaq, thanks to her work near and involvement of local collaborators. This approach helped to overcome several identified shortcomings, including a lack of trust; communication difficulties; an incomplete picture of needs, particularly those of the community; and the resulting lack of commitment. Thanks to the bonds of trust established, the participation of Kuujjuaq residents made it easier to define priority needs and identify effective and sustainable solutions that will, de facto, be supported by the community with high acceptability.

In this model, multisectoral coordination and collaboration at national, regional, and departmental levels, combined with community participation, are the central elements around which 4 essential pillars revolve. Collaboration and coordination are among the regional measures advocated by WAHO to deal with priority zoonotic diseases as part of the "one health" approach [16].

Prominent among the strategies implemented are those aimed at improving people's knowledge of the disease and improving financial and geographical accessibility to PEP. About improving people's knowledge of the disease, numerous communication and awareness-raising activities are carried out on an ad hoc basis during the World Rabies Control Days initiated in Cote d'Ivoire in 2008, and other ad hoc activities in schools or targeting pupils and teachers. Despite these activities, deaths are still caused by failure to use PEP after exposure. We therefore advocate the ecohealth approach, one of the essential pillars of which is community participation. We need to involve communities and ensure that they take real ownership of the fight against rabies. The influence of knowledge about rabies on compliance with PEP means that we can insist on communication to increase knowledge about rabies and increase the use of PEP.

Affordability

When the intradermal route is used for post-exposure prophylaxis, it reduces the number of vials of vaccine used by at least 25% compared with the intramuscular route. As the number of patients attending health centres increases, the intradermal route is becoming increasingly cost-effective, reducing the number of vials of vaccine used by up to 85%. Furthermore, according to [17], the cost of post-exposure prophylaxis for a severely exposed child varies from \$28.75 to \$125.00. Pre-exposure vaccination is only \$2.00 to \$7.25, with an additional cost of \$18.00 to \$23.50 if the post-exposure booster vaccination is required later. Lower costs have been estimated using the WHO-approved reduced-dose intradermal vaccination schedule. Budgetary constraints in developing countries where rabies is endemic need to consider healthcare costs as well as better care protocols [17].

Implementing this protocol could considerably reduce the cost of PEP by 80%, making it accessible to all populations, especially the poor. However, this affordability should be put into perspective for category 3 exposures, where the use of rabies immunoglobulin is required. In legal and regulatory terms, the Cote d'Ivoire National Committee of Independent Experts on Vaccines and Immunisation has authorised the use of intradermal vaccines for pre- and post-exposure prophylaxis in Cote d'Ivoire. Similarly, the Cabinet of the Ministry of Health, Public Hygiene and Universal Health Coverage has authorised its implementation at national level. Finally, a feasibility study on the use of the WHO protocol combined with public awareness campaigns carried out in Bouake and San Pedro showed strong support and increased compliance with rabies PEP.

Implementing Pre-Exposure Vaccination

Implementing high-quality PEP that is geographically and financially accessible is the key to combating rabies mortality. Based on the recommendations of the Cote d'Ivoire National Committee of Independent Experts on Vaccination and Vaccines, the cabinet's authorisation and the results of feasibility studies carried out in Bouake and San-Pedro, the WHO's intradermal protocol will be widely used at all site's where exposed subjects are treated. These studies show that the free intradermal rabies vaccine considerably increases the use of and compliance with PEP in Cote d'Ivoire. Therapeutic education for patients receiving PEP is a prerequisite for getting people to adhere to full PEP.

Furthermore, in the case of category 3 exposures, this implementation could compensate for the absence of rabies immunoglobulin. The feasibility study carried out showed that the pre-exposure prophylaxis protocols were well accepted and, above all, adhered to. In addition, pre-exposure vaccination is more effective than PEP.

Stepping up Animal Vaccination

Canine mass vaccination campaigns can interrupt canine-to-canine transmission of the virus, on which the incidence of canine rabies depends considerably. Vaccination coverage of at least 70% should completely stop canine-to-canine transmission. According to [19], a mass vaccination campaign against canine rabies provided free of charge, repeated once or twice, and covering the whole of Chad each time is a feasible and cost-effective way of eliminating rabies nationwide [19]. These strategies are supported by multisectoral coordination and collaboration, epidemiological surveillance, awareness raising and communication to achieve sustainable behaviour change.

All the activities recommended in the model will need to be backed up by support activities, in particular:

- Epidemiological surveillance, including investigation and response
- Community involvement by CHWs
- Monitoring and evaluation of activities

Ultimately, a combination of interventions will be required. All these interventions, if implemented concurrently, could improve the use of and compliance with PEP, pending control of canine rabies through vaccination coverage of at least 70%, and enable the country to achieve the goal of eliminating dog-transmitted human rabies by 2030. The implementation of this model could face the following challenges: insufficient financial resources to fund the model's activities, challenges linked to collaboration between health workers in the animal and human health sectors, and ownership of the fight by the population. However, the political will demonstrated by the country's adherence to the initiative to eliminate dog-transmitted rabies by 2030, and the adoption of the integrated plan for rabies control in Cote d'Ivoire, could help overcome these challenges.

Conclusion

Numerous risk factors persist, the low level of knowledge of the disease, the lack of systematic recourse to PEP, poor compliance with PEP and, above all, low vaccination coverage in dogs, the main reservoir of the disease in Cote d'Ivoire. The proposed integrated pest management model is adapted to the characteristics of the disease in Cote d'Ivoire. These activities need to be implemented in a coordinated and integrated manner. Pending control of the germ reservoir, PEP should be systematically implemented in the event of any exposure to rabies. Under these conditions, it is essential to raise awareness among the population, with their full participation, and to generalise PEPD in order to reduce the cost and improve access to PEP.

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